Surface Passivation of Lithium-Ion Electrodes: A Path to High-Performance Energy Storage

Completed Technology Project (2012 - 2016)

Project Introduction

Energy storage is one of the most crucial aspects of space technology. Whether the energy is stored as fuel in the solid rocket boosters or as electrochemical energy in the onboard batteries, the need for on-demand power is essential. Some functions of spacecraft such as life-support and lighting require continuous electrical energy, but a large majority of other functions such as communications, guidance, and control electronics only require it intermittently. This places a widely varying electrical load on the power systems of the spacecraft that in some cases cannot be handled directly by the constant energy output of solar or thermoelectric power generation systems. In these cases the electrical power is supplied as needed in part or wholly from rechargeable battery banks. These batteries must have a long cycle life, high energy density and high power density to meet the rigorous demands of spacecraft avionics. In addition they also have to be light-weight, compact and able to withstand extreme operating conditions; a consideration for every component sent into space. The importance of secondary battery systems in spacecraft and space exploration equipment cannot be overstated, making them a vital space technology. Of the currently available rechargeable battery technologies, lithium-ion (li-ion) batteries have the best combination of high specific energy density, high volumetric energy density and acceptable cycle life. However, current li-ion technology has cost, toxicity, and high temperature cyclability issues. This project seeks to overcome the deficiencies of current li-ion battery technology and meet the electrical energy requirements for long-duration space missions through the development of a high-performance li-ion cathode based on the lithium nickel manganese spinel ($LiNi_{0.5}Mn_{1.5}O_4$ or LNM). LNM has advantages of low-cost and low-toxicity over current li-ion technology because it does not use cobalt, an expensive and toxic element. Also, LNM has higher specific energy density and power density over current layered lithium cobalt oxide cathodes because of its higher operating voltage and increased capacity. However, LNM does suffer from unfavorable cyclability at elevated temperatures due to increased reactivity with the electrolyte, a problem that can be mitigated or solved through surface passivation. Doping the material with foreign elements and processing the cathodes under sufficient synthesis conditions can lead to surface passivation through reorganization of the surface structure. This renders the surface kinetically stable upon cycling by creating a stable solid-electrolyte interphase (SEI) layer which protects the electrolyte from further oxidation/reduction. The exact mechanism of surface passivation of LNM by doping and its connection to surface restructuring is not known. The goals of this project are to identify the surface passivation mechanism of the doping method in the LNM system and its connection to surface restructuring and use that knowledge to optimize composition and synthesis conditions to improve cyclability of LNM. Advanced electron microscopy techniques such as aberration-corrected scanning transmission electron microscopy (STEM) and electron energy loss spectroscopy (EELS) combined with traditional analysis techniques such as x-ray diffraction (XRD) and time-of-flight secondary ion

Project Image Surface Passivation of Lithium-Ion Electrodes: A Path to High-Performance Energy Storage

Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

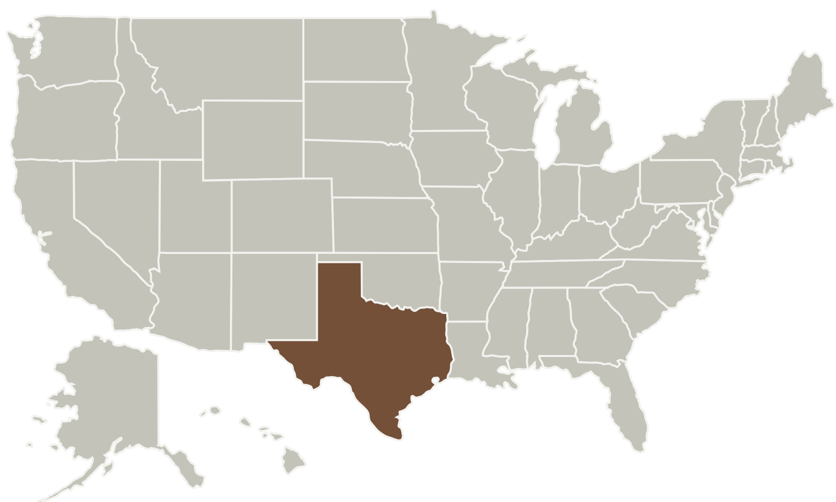
Space Technology Research Grants

mass spectrometry (TOF-SIMS) will be employed to analyze surface/bulk compositions and structures of the material with different dopants processed under varying processing conditions. The knowledge gained from these experiments will lead to a next-generation li-ion battery with superior energy storage and cycling capabilities that is robust enough to endure the extreme conditions of space duty. This represents an innovative and important scientific contribution to NASAs space technology and more broadly, the many technologies that can benefit from portable, high performance electrical energy storage.

Anticipated Benefits

The knowledge gained from these experiments will lead to a next-generation li-ion battery with superior energy storage and cycling capabilities that is robust enough to endure the extreme conditions of space duty. This represents an innovative and important scientific contribution to NASAs space technology and more broadly, the many technologies that can benefit from portable, high performance electrical energy storage.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
The University of Texas at Austin	Supporting Organization	Academia	Austin, Texas

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

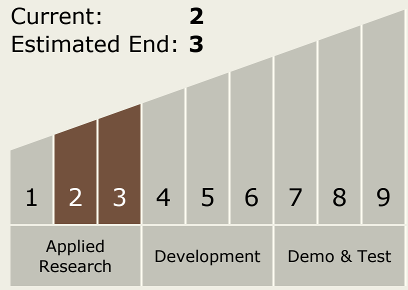
John Goodenough

Co-Investigator:

Charles D Amos

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX03 Aerospace Power and Energy Storage
  └─ TX03.2 Energy Storage
    └─ TX03.2.1 Electrochemical: Batteries

Primary U.S. Work Locations

Primary U.S. Work Locations
Texas

Images

11481-1363266425663.jpg
Project Image Surface Passivation of Lithium-Ion Electrodes: A Path to High-Performance Energy Storage
(https://techport.nasa.gov/image/1830)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html